COMPOSITE STRUCTURE

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BACKGROUND

The present invention relates to elongated structures such as pilings of the type used in marine applications for protecting piers, docks and similar structures from being damaged by passing and docking ships, and methods for making such pilings.

Concrete, steel, and wood are conventionally used for pilings, telephone poles, and the like. However, each of these materials has disadvantages. Concrete and steel pilings are heavy and awkward to maneuver. Neither concrete nor steel pilings make good fender pilings because neither is "forgiving" when impacted. Under impact steel bends and buckles and concrete shatters. Both concrete and steel pilings are expensive to repair. Furthermore, steel, either standing alone or as a reinforcement in porous concrete, is subject to corrosion.

Wood pilings are plagued by wear and tear and are attacked by wood-boring marine organisms. Wood pilings are typically treated with creosote, but even this material can be ineffective against modern marine borers. These marine borers can only be stopped by wrapping the wood pilings in plastic coverings. However, these plastic coverings cannot withstand much wear and tear, especially abrasion from

normal vessel contact. So in addition to a thin plastic wrap, wooden fender piles often require thick plastic wrappings, which are expensive to put in place. Wood used for telephone poles is subject attack from environmental hazards such as woodpeckers, and in desert locations, there can be severe erosion from sandstorms.

Composite pilings are also known, being disclosed for example in U.S. Patent No. 5,180,531 to Borzakian, that document being incorporated herein by this reference. The '531 patent discloses a plastic pipe having an inner pipe core or mandrel being 6 inches or less in diameter, and a substantially homogenous coating being at least two inches thick. The thick plastic coating provides the bulk of the mechanical strength, being formulated with a desired combination of flexibility, brittleness, and impact resistance for use as pilings including fender pilings of docks, telephone poles, light standards, etc. The plastic pipe of the prior art is not entirely satisfactory in that uniform thick coatings that are free of voids are somewhat difficult to achieve, and longer lengths of the pilings such as from 20 feet to 60 feet normally require assembly of shorter length segments, with consequent degradation of structural and environmental integrity and increased cost of fabrication. Also, when the plastic pipe is provided with the homogenous plastic coating having with a desired flexibility and impact resistance for fender piling applications, the bending strength is less than desired for withstanding side loads that are produced by contact with approaching vessels. Pilings of similar construction incorporating larger pipe mandrels are also known.

U.S. Patent No. 5,766,711 to Barmakian discloses a composite camel structure including a pipe mandrel and a thermally bonded plastic cushion surrounding the mandrel,

that patent being incorporated herein by this reference. A mold having the mandrel centered therein is filled with molten plastic, the plastic being cooled and solidified by feeding water into the mandrel for progressively solidifying the cushion member along mandrel for producing a thermal bond without excessive tensile strain in the plastic material, thereby to achieve a substantially unbroken outside surface.

Another known form of composite piling, which is described in U.S. Patent No. 6,244,014 to Barmakian and incorporated herein by this reference, incorporates a welded cage structure including longitudinal bars that are connected by a spiral member, the cage structure being encapsulated in a resilient plastic.

A further form of composite pilings incorporates a thin-wall cylindrical tubular member formed of carbon filament-reinforced plastic that is filled with concrete. Unfortunately, it is prohibitively expensive to orient the carbon filament diagonally. Commercially available tubular members of this type have a substantially purely circumferential filament orientation and consequently this type has little bending and shear strength, even in combination with the concrete core. Further, these pilings are quite brittle, having little ability to withstand side impacts by ships and other vessels in marine applications.

In view of these problems with existing thin-wall pilings, there is a need for elongated structures for marine use that are inexpensive to provide, yet have a long life, are easily installed, environmentally sound, durable in use, having high bending and shear strength. There is a further need for such structures having great energy absorbing capacity when subjected to side impact loads.

SUMMARY

The present invention meets these needs by providing a composite structure that is low in cost and has particularly high bending and shear strength. In some preferred configurations the structure also has a very great ability to withstand high energy side impact loading. In one aspect of the invention, the reinforced composite structure includes an elongate tubular member having first and second ends, a second end portion near the second end, a length of at least 10 feet, an outside surface defining an outer cross-sectional area of at least 28 square inches at a first location along the tubular member, and an inside surface defining a wall thickness of not more than 10 percent of an equivalent diameter of the outer cross-sectional area at the first location; and a resilient plastic body encapsulating only a portion of the outside surface of the tubular member including a portion near the first end, the plastic body extending on the outside surface of the tubular member not closer to the second end than 20 percent of the length of the tubular member for facilitating secure and rigid planting of the composite structure in soil. Preferably the encapsulation extends lengthwise on the outside surface of the tubular member for at least three equivalent diameters of the outer cross-sectional area outside and inside surfaces for enhanced structural integrity of the plastic body. The encapsulated portion of the tubular member can extend to the first end of the tubular member, it can be approximately flush with the first end of the tubular member, or it can encapsulate the upper end of the tubular member. Also, the plastic body can substantially fill the tubular member.

The tubular member can include a fiber-reinforcing material, such as fiberglass.

Preferably the composite structure includes a reinforcing element contacting the inside surface of the tubular member. The reinforcing element can include a shear-resistant material substantially filling the tubular member. The shear-resistant material can be concrete. Also, or in the alternative, the reinforcing element can include an elongate reinforcing member extending within the tubular member and being in proximate contact with a portion only of its inside surface. The reinforcing member can include a longitudinally distributed plurality of loop elements. Adjacent loop elements of the reinforcing member can have a pitch spacing between approximately 25 percent and approximately 70 percent of the equivalent outside diameter of the tubular member, and the loop elements can be helically formed. The reinforcing member can include a material selected from steel, nickel, carbon fiber, and fiberglass. The reinforcing member can have a cross-sectional area of between 0.02 percent and approximately 0.2 percent of the overall cross-sectional area of the tubular member.

Preferably at least a portion of the plastic body has a radial thickness outside of the tubular member that is not less than approximately 5 percent of a co-located circumference of the tubular member, the term co-located meaning located along the tubular member within the portion of the plastic body.

Preferably the plastic body consists of a main polymeric component and an additive component, the main polymeric component consisting of low-density polyethylene of which at least 60 percent is linear low density stretch

film polyethylene, the additive component including an effective amount of an ultraviolet inhibitor. More preferably, the main polymeric component is at least 90 percent of the plastic body, the plastic body including not more than 5 percent by weight of high-density polyethylene.

In another aspect of the invention, a method for forming a composite structure includes the steps of providing an elongate tubular member; and encapsulating an end portion of the tubular member in a plastic body, the tubular member having an overall length of not less than approximately 10 feet, an overall cross-sectional area of at least 28 square inches at an axial extremity of the plastic body closest to the second end of the tubular member, and a wall thickness being not more than 10 percent of a diameter equivalent to said overall cross-sectional area.

The method can include the further step of inserting a reinforcing element into the tubular member, the reinforcing element contacting the inside surface for stiffening the tubular member. The reinforcing element can include a reinforcing member, the method including the further steps of forming the reinforcing member as a rod member having a longitudinally spaced plurality of loop elements and, prior to the encapsulating, inserting the rod member into the tubular member with at least a portion of each of the loop elements contacting circumferentially spaced locations on the inside surface of the tubular member.

Alternatively, or additionally, the step of inserting can include feeding a liquidic reinforcing material into the tubular member, and solidifying the liquidic material. The liquidic material can include material of the plastic body and/or concrete.

The encapsulating can include the steps of providing an injection mold having an elongate cylindrical cavity; loading the mold with the tubular member such that a portion of the tubular member projects from a main cavity portion of the mold; injecting a polymeric composition into the mold thereby encapsulating a portion of the tubular member; and cooling the mold to form the composite structure. Preferably the step of injecting includes formulating the polymeric composition to consist of low density polyethylene, at least 60 percent of the polymeric composition being linear low-density stretch film polyethylene for resisting cracking of the material.

In a further aspect of the present invention, a method for forming a cushioned fender in a marine environment having underwater soil, includes the steps of selecting a reinforced composite structure as first given above; and driving the second end of the tubular member into the soil to a depth effective for stabilizing the tubular member and for positioning the plastic body as a cushioned barrier above the soil.

DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood with reference to the following description, appended claims, and accompanying drawings, where:

Figure 1 is a sectional elevational view of a reinforced composite piling according to the present invention, the piling being installed in a marine environment for fending off passing vessels;

Figure 2 is a bottom view of the piling of Fig. 1;

Figure 3 is a sectional elevational view as in Fig. 1, showing an alternative configuration of the composite piling;

Figure 4 is a lateral sectional view of a mold assembly in use making the composite piling of Fig. 1, illustrating the flow of extruded plastic within and around a spiral reinforcing member thereof; and

Figure 5 is a flow chart for a process of forming the piling structure of Fig. 1.

DESCRIPTION

The present invention provides a novel reinforced composite structure that is particularly effective as a fender in association with a ship mooring or other harbor structure. With reference to Figs. 1 and 2 of the drawings, a composite structure or piling 10 according to the present invention includes an elongate tubular member 12 and a resilient plastic material forming a plastic body 14 encapsulating an upper portion of the tubular member. As shown in Fig. 1, the piling 10 can be implanted in soil 16 under a body of water 18 such that the plastic body 14 is positioned for blocking the hull of a ship 20 in a cushioned manner, the plastic body being confined to that portion of the tubular member 12 that is not in the soil 16.

An exemplary configuration of the piling 10 has the tubular member 12 and an outer perimeter of the plastic body 14 formed generally circularly cylindrical with a diameter B at a distance W outwardly from the tubular member 12 as shown in Fig. 2, the tubular member having an outside diameter D (See Fig. 1.) that is typically between 8 and 36 inches, and a length L that is typically between

approximately 10 feet and approximately 60 feet. Even longer lengths such as 100 feet are also contemplated, although coupling to extension pilings in locations of deep mud deposits is generally preferred. A preferred embodiment of the tubular member 12 is formed of glass fiber-reinforced epoxy (referred to herein as "fiberglass"), having a wall thickness T that can be from approximately 0.125 inch up to approximately 2 inches. As used herein, the term "cylindrical" means having a surface that is generated by a straight line that moves parallel to a fixed line. Thus, although the tubular member 12 and the perimeter surface of the body 14 are shown in the drawings as being circularly cylindrical, other cross-sectional shapes such as elliptical, polygonal, and rounded polygonal are also contemplated within the scope of the present invention. In these alternatives, the tubular member 14 typically has an overall cross-sectional area of at least approximately 50 square inches, although smaller sections such as having approximately 28 square inches are contemplated, being equivalent to approximately 6 inches diameter. Further, this invention is not limited to cylindrically shaped cores, as axially tapered and other tubular shapes are contemplated. Moreover, other materials are contemplated for the tubular member, including carbon filament-reinforced plastic and steel.

Also, although the plastic body 14 is shown radially projecting a uniform distance W outwardly from the tubular member 12 to a body diameter B for a distance or encapsulated length ℓ downwardly from the upper extremity of the tubular member, the body 14 need not be concentric with the tubular member 12. Further, the perimeter surface of the body 14 is not required to be circular or even cylindrical; a variety of other shapes such as frusto-

conical and ellipsoidal are contemplated within the scope of the present invention, although at least a portion of the plastic body preferably has a radial thickness outside of the tubular member being not less than approximately 5 percent of a co-located circumference of the tubular member. Moreover, the plastic body 14 projects outwardly from the tubular member over a body length C, which can extend a distance E beyond the upper end of the tubular member 12, the piling 10 having an overall length F. As further shown in Fig. 1, the composite piling 10 extends to a height H above the soil 16 when driven a sink distance S into the soil. The sink distance S will normally be at least 20 percent of the length L of the tubular member 12. Accordingly, the encapsulated length ℓ is normally less than 80 percent of the length L, preferably less than 75 percent of the length L for avoiding contact with or partial penetration with the soil, with consequent potential for partial separation of the plastic body from the tubular member and/or reduced stiffness of the implantation of the piling 10. Also, the encapsulated length ℓ is normally not less than approximately 3 times the diameter D of the tubular member. More generally for tubular members of non-circular cross-section, the encapsulated length ℓ is not less than 3 equivalent diameters of the tubular member, the term equivalent diameter being the diameter of a circular cross-section having the same area as that of the non-circular cross-section. More preferably, the encapsulated length ℓ is between approximately 30 percent and approximately 50 percent of the length L for providing effective cushioning over an expected range of contact locations while avoiding the use of ineffective quantities of material of the plastic body 14.

An optional feature of the composite piling 10 is a reinforcing element that extends proximate an inside surface 24 of the tubular member for resisting inward deformation of the tubular member under high transverse loading such as when the piling 10 is subjected to impact contact by the ship 20, or in the event that the ship 20 being restrained by the piling is subjected to high winds. In the exemplary configuration of Figs. 1 and 2, the reinforcing element is a reinforcing member 22 in the form of rod of generally uniform cross-section having helically formed loop elements 23 that contact the inside surface 24 of the tubular member 24 along substantially the full length thereof.

In the exemplary configuration of Figs. 1 and 2, the plastic body 14 substantially fills the space inside the tubular member 12 that is not occupied by the reinforcing member 22. In applications wherein bending loading is not severe, the reinforcing member 22 can be omitted and the plastic body 14 filling at least a portion of the tubular member functions as the reinforcing element. In applications having severe bending loads, a reinforcing structure (incorporating the reinforcing member 22 or in addition thereto) can be imbedded in the tubular member. (The glass fibers of the exemplary fiberglass tubular member 12, described above, serve as such a reinforcing structure.) The reinforcing member 22 can be a conventional formed steel reinforcing rod of the type commonly used for reinforcing concrete (available, for example from J.L. Davidson Co. of Rialto, CA). Other suitable forms of the reinforcing member 22 include nickel reinforcing rod (available from MMFX Steel Corp. of America, Charlotte, NC), fiberglass reinforcing rod (available from Hughes Brothers fiberglass of Seaward, NE,

and carbon fiber reinforcing rod (available from Aero Space Composite Products of San Leandro, CA).

In a preferred configuration wherein the outside diameter D of the tubular member 12 is on the order of 8 or 10 inches, the thickness T being between approximately 0.12 inches and approximately 0.25 inches, a suitable diameter of the reinforcing member 22 is nominally 3/8 inch in diameter. A suitable spacing or pitch P of the loop elements 19 is approximately 5 inches, or about half of the outside diameter D. More generally, the diameter of the reinforcing member 22 can be from approximately 0.25 inch to approximately 0.75 inch.

In a variety of applications, it is contemplated that the outside diameter D of the tubular member 12 can be from approximately 8 inches to approximately 36 inches. The radial thickness W of the plastic body 14 can range from approximately 0.25 inch to approximately 24 inches. Practical combinations of these dimensions include the wall thickness T of the tubular member being from approximately 1.5% to approximately 10% of D, the radial thickness W of the plastic body 14 being from approximately 3% to approximately 100% of the diameter D of the tubular member 12.

With further reference to Fig. 3, an alternative configuration of the composite piling, designated 10', incorporates a shear member 30 that preferably fills the space within the tubular member 12 that is not occupied by the reinforcing member 22. A suitable and preferred material for the shear member 30 is concrete. It will be

An important feature of the present invention is a formulation of polymeric material that is suitable for

encapsulating the tubular member 12 and that does not form voids and cracks due to tensile thermal strains being generated during solidification. This problem is exacerbated by the absence of a tubular mandrel that can receive cooling water as disclosed in the camel structure of the above-referenced '711 patent. As described in the above referenced U.S. Patent No. 6,244,014 which is incorporated herein, it has been discovered that a particularly suitable composition for forming the plastic body 14 as an uninterrupted covering that also fills the tubular member 12 is a main first quantity of low density polyethylene of which at least 60 percent and preferably 65 percent is linear low-density polyethylene (LLDPE), the balance being regular low-density polyethylene (LDPE), and a process additive second quantity which may include a foaming or blowing agent, a coupling agent, a fungicide, an emulsifier, and a UV inhibitor such as carbon black, the composition not having any significant volume of filler material such as calcium carbonate. Preferably, the first quantity is at least 90 percent of the total volume of the plastic body 14, approximately 5 percent of the total volume being a mixture of coloring, foaming agent, and UV inhibitor. Preferably the composition is substantially free (not more than 5 percent) of high density polyethylene.

Thus the composition of the cushion member 14 has polymeric elements being preferably exclusively polyethylene as described above (substantially all being of low-density and mainly linear low-density), together with process additives. As used herein, the term "process additive" means a substance for enhancing the properties of the polymeric elements, and does not include filler material such as calcium carbonate.

With further reference to Fig. 4, a mold apparatus 40 for encapsulating the cage 12 to form the plastic body 14 of the piling 10 includes a mold assembly 42, a mold cradle 44, and a conventional extruder press having an outlet 46. The mold assembly 42 includes a flanged tubular mold segment 48, an inlet plate 50 having an injection point 52 for connection to an outlet of the extruder press, and a back plate 54 through which the tubular member 12 projects, the back plate 54 having an exhaust vent 55.

As further shown in Fig. 4, the mold segment 48 has an inside diameter D′ and a length L′, being a weldment of a mold tube 78 and a pair of perforate flanges 80. The diameter D′ and the length L′ of the mold segment 48 correspond to the body diameter B and length C, but with allowance for shrinkage of the material of the plastic body 14. For example, with the inside diameter D′ being 13.25 inches, the body diameter B subsequent to cooling of the plastic body 14 is approximately 13.0 inches. Respective pluralities of flange fasteners 84 provide removable connections between the flanges 80 and the corresponding inlet and back plates 50 and 54. Suitable materials for the mold tube 78 and the flanges 80 include mild steel of 0.25 inch and 1 inch thickness, respectively. It will be understood that additional counterparts of the mold segment 48 can be connected end-to-end with the segment 48 for selectively varying the length C of the body member 14.

Also shown in Fig. 5 is the tubular member 12 centered within a main cavity 60 of the mold assembly 42, being supported relative to the back plate 54 and a rear element 62 of the mold cradle 44 that also supports the mold assembly 42. The back plate 54 is provided with a plurality of flanged inserts 56 that are fastened thereto by fasteners 58 for facilitating insertion of the tubular member 12 as

well as for providing an effective seal between the back plate 54 and the tubular member. The rear element 62 has a cavity 64 formed therein for locating the projecting extremity of the tubular member 12, the cavity 64 closely fitting the outside of the tubular member to provide a seal for the material of the body member 14 being molded therein, and having a counterpart of the exhaust vent, designated 55'. The mold cradle 44 also includes a medial element 66 and a front element 68 on which rests the mold tube 78, the medial element also engaging the perforate flange 80 to which the back plate 54 is fastened for limiting the projection of the tubular member from the mold assembly 42. Further, the rear element 62 is stepped as indicated at 70 for facilitating location of the tubular member 12 first by lowering the member and then by axially displacing the member outwardly from the mold assembly 42. Alternatively, the rear element 62 can be assembled from a cradle portion and a cavity portion, the cavity portion being attached subsequent to positioning of the mold assembly 42 and the tubular member, and this form of the rear element 62 can be made a part of the mold assembly 42. Additionally or alternatively to the centering by the rear element 62, the tubular member can be centered within the mold assembly 42 by means described in the above-referenced U.S. patent 6,244,014, provided that a suitable means for keeping the tubular member axially located is included.

The mold assembly 42 and the mold cradle 44 can also be used in formation of the composite piling 10' of Fig. 3, the shear member 30 having been formed by conventional means prior to molding the plastic body 14. In this embodiment, there is no need for sealing engagement at the projecting extremity of the tubular member 12 or for the exhaust vent 55'.

With further reference to Fig. 5, a molding process 100 for forming the composite structure or piling 10 includes inserting the reinforcing member 22 into the tubular member 12 in a load reinforcing step 102, a form shear member step 103 (when the process 100 is for forming the piling 10'), a load mold step 104 wherein the tubular member 12 is placed within the mold assembly 42 with one end thereof projecting from the back plate 54, a cradle step 106 wherein the tubular member 12 is coaxially centered within the mold tube 78 by being supported, for example, by the rear element 62 of the mold cradle in combination with the back plate 54, the tubular member also projecting a predetermined distance from the back plate 54 corresponding to the extension distance E being that desired. The mold assembly 42 is closed, for example, by installing the inlet and/or back plates 50 and 54, in a close mold step 108 and, optionally in an incline mold step 110, the mold assembly 42 is propped up on a suitable support for elevating the exhaust vents 55 and 55'. It will be understood that the back plate can be attached to the medial element 66 prior to connecting the mold tube 78. Also, the mold cradle 44 can be constructed so as to support the mold assembly 42 in an inclined condition initially. Further, it may be desirable to bond or otherwise fixably locate the reinforcing member to the inside surface 24 of the tubular member 12 for increased bending strength of the composite piling 10.

Next, the material of the plastic body 14 is fed into the main cavity 60 in an inject body step 112. Then in a cooling step 114, the mold assembly 42 with its contents is submerged in cooling water for solidifying the material of the plastic body 14, after which the assembly 42 is removed from the water (step 116), opened and the completed piling 10 is withdrawn in a remove structure step 118.

If desired or needed, the tubular member 12 and/or the mold assembly 42 can be preheated to be certain that the plastic material of the cushion member 14 flows to the cover plate 54 of the mold assembly 42 and completely fills the main cavity 60 as well as the tubular member 12.

The piling 10 of the present invention is immune to marine borer attack, and thus requires no further protection, such as creosote or plastic sheathing, being practically maintenance free. The piling 10 is abrasion resistant, and thus has excellent effectiveness as a marine fender piling without any added protective covering.

The composite piling 10 is chemically inert, so it can last indefinitely. It does not react with sea water, is corrosion free, is substantially immune to the effects of light, is not bothered by most petroleum products, and is not subject to dry rot. Because it can be made with recycled plastic, it is an environmentally sound investment.

In some military based naval applications, it is undesirable for a piling to be electro-magnetically sensitive. In such applications the reinforcing member 22 can be formed with non-magnetic materials, such as carbon-reinforced plastic.

Although the present invention has been described in considerable detail with reference to certain preferred versions thereof, other versions are possible. For example, the tubular member 12 can be flush with one end of the plastic body 14, or the tubular member project from both ends of the plastic body. In the first case, the inlet plate 50 would be formed for feeding the material for the plastic body 14 of the piling 10 of Figs. 1 and 2 both outside and inside of the tubular member 12. In the second

case, separate paths for the material for the plastic body 14 would be provided, either in a single operation or separate molding operations. Similarly for the piling 10' of Fig. 3, the inlet plate 50 would be formed for feeding material outside of the tubular member only, such as by incorporating a pair of injection points 52 on opposite sides of counterparts of the flanged inserts 56. Therefore, the spirit and scope of the appended claims should not necessarily be limited to the description of the preferred versions contained herein.